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Optical and gain properties of series of crystals $LiF–YF_3–LuF_3$ doped with Ce^{3+} and Yb^{3+} ions

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Abstract

Here, we present first results of systematic studies of host cation variation impact on spectral-kinetic, photochemical and gain properties of Ce^{3+}-doped $LiYF_4$ (YLF), $LiLuF_4$ (LLF) and $LiY_{1-x}Lu_xF_4$ family crystals. 5d–4f luminescence decay of Ce^{3+} ions studies, together with pump–probe experiments, indicate that previously reported twice higher luminescence quantum yield in LLF compared with that of YLF crystals is provided by more efficient upper lasing level feeding due to recombination and higher color center destruction rate in LLF against YLF crystals. Namely, it is responsible for higher energetic characteristics of laser based on Ce^{3+}:LLF crystals. Strong and wide pump-induced absorption band centered at 310 nm is observed in Ce^{3+}:YLF. This band is shifted to blue and its intensity goes down with Lu content. We have evaluated free charges recombination rate, excited state absorption cross-section for Ce^{3+} ions and some other photodynamic processes related microparameters. Fitting results indicate that pump-induced color centers lifetime decreases with Lu-content in $LiYF_4–LiLuF_4$ mixture and it can be associated with more efficient color center bleaching by Ce^{3+} ions 5d–4f fluorescence.

Keywords: 5d–4f interconfigurational transition; UV solid-state active medium; Color center; Pump–probe experiments

1. Introduction

UV and VUV quantum electronic devices, based on 5d–4f transitions of trivalent rare-earth ions in wide band gap dielectric crystals, offer some important advantages against the traditionally used ones. However, most media of this type pertinent for UV applications experience problems related to photodynamical processes resulting mainly in solarization effect, which comes after active ion multiphoton stepwise ionization by intense UV pumping [1]. Impurity ions photoionization not only withdraws energy from inversed population in the active media, but pump-induced color center absorption contributes to the total losses and increases laser oscillation threshold leading to ineffective and transient laser action [2,3]. Now, it is obvious that activator ions and host lattice interaction is the key factor in photochemical conversions under intense UV pumping and, therefore, in laser performances.

Host lattice structure and cationic set determine dopand's energy levels, structure and positions relatively to host bands and therefore host cation change impact on both spectral-kinetic and photochemical properties of activated crystals. It is most appreciable for $4f^n–4f^{n-1}5d$ interconfigurational transitions of rare-earth ions since 5d-electronic orbitals are expanded far away from the core and thus very sensitive to ligand environment [4]. It is very well demonstrated by numerous studies of optical properties of crystal families doped by Ce^{3+} ions (see e.g. $CaF_2–SrF_2–BaF_2$ [5], $LiYF_4–LiLuF_4$ [6]). Thus, cationic set modification seems to be a great opportunity to manage active media basic optical and photochemical properties and to achieve a success in realization of an effective UV laser action based on $4f^{n-1}5d–4f^n$ interconfigurational transitions. This can be achieved due to two reasons. First, by choosing appropriate host cationic set we can obtain crystal with wider band gap and therefore reduce an

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